

**DEVELOPMENT PLAN FOR A DIVERSION
INTO
THE MAUREPAS SWAMP
Water Quality and Hydrologic Modeling Components**

FINAL REPORT

Prepared for:

U.S. Environmental Protection Agency

Region 6

1445 Ross Avenue, Suite 1200

Dallas, Texas 75202-2733

UNDER

COOPERATIVE AGREEMENT X-986946-01

By:

John W. Day, Jr.

G. Paul Kemp

Hassan S. Mashriqui

Robert R. Lane

Dane Dartez

Robert Cunningham

Louisiana State University

School of the Coast & Environment

Natural Systems Modeling Group

1002Q Energy, Coast & Environment Bldg.

Baton Rouge, Louisiana 70803

September 2004

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1.0	INTRODUCTION.....	1
1.1	Study Objectives.....	4
1.2	River Diversion Science.....	5
1.2.1	The Nutrient Issue.....	7
1.3	Balancing Benefit and Risk in Maurepas.....	12
2.0	STUDY AREA.....	15
2.1	Swamp Ecology.....	28
2.2	Water Quality.....	31
2.3	Hydrology.....	34
3.0	METHODS.....	38
3.1	Field Program.....	38
3.1.1	Water Quality Sampling.....	38
3.1.2	Hydrologic Gaging.....	42
3.2	Modeling Program.....	46
3.2.1	Selection and Description of TABS Model Suite.....	47
3.2.1.1	<i>Swamp Geometry.....</i>	56
3.2.1.2	<i>Calibration.....</i>	59
3.2.1.3	<i>Validation.....</i>	78
3.2.2	Ecological Forecasting.....	85
3.2.2.1	<i>Forest Patchiness.....</i>	85
3.2.2.2	<i>Nutrient Model.....</i>	87
3.2.2.3	<i>Stress Dynamics.....</i>	92

4.0	RESULTS AND DISCUSSION.....	96
4.1	Water Quality	96
4.1.1	Nitrogen	96
4.1.2	Phosphorus.....	97
4.1.3	Silicate.....	99
4.1.4	Si:N:P Ratios.....	99
4.1.5	Salinity.....	99
4.1.6	Suspended Sediments and Chlorophyll a.....	100
4.2	Swamp Geometry and Hydrology.....	101
4.2.1	Swamp Geometry	101
4.2.2	Swamp Hydrology.....	102
4.2.2.1	<i>Lake Group.....</i>	103
4.2.2.2	<i>River Group.....</i>	106
4.2.2.3	<i>Diversion Group.....</i>	106
4.2.2.4	<i>Swamp Group.....</i>	110
4.2.2.5	<i>Canal Group.....</i>	111
4.3	Hydrodynamic and Water Quality Modeling.....	114
4.3.1	Base Case Analysis.....	114
4.3.1.1	<i>Runoff from the Amite River.....</i>	115
4.3.1.2	<i>Swamp Inundation.....</i>	115
4.3.1.3	<i>Salinity.....</i>	120
4.3.2	Diversion Analysis.....	120
4.3.2.1	<i>Inundation Duration.....</i>	120

	<i>4.3.2.2 Salinity Reduction.....</i>	123
	<i>4.3.2.3 Constituent Transport.....</i>	124
4.4	Ecological Forecasting.....	130
	4.4.1 Forest Characteristics from LIDAR.....	130
	4.4.2 Nutrient Assimilation.....	131
	4.4.3 Long-Term Ecological Simulation.....	136
	<i>4.4.3.1 The Individual Oriented Model Approach.....</i>	136
	<i>4.4.3.2 SWAMPSUSTAIN – a Sediment-Driven Approach</i>	138
5.0	CONCLUSIONS.....	148
6.0	ACKNOWLEDGEMENTS.....	155
7.0	REFERENCES.....	156
8.0	APPENDIX.....	167

9.0	LIST OF TABLES	
3.1	Maurepas Hydrologic Gaging Program: 2002 – 2004.....	44
3.2	Calibration Results (ft) for Maurepas Stations: December 26, 2003 to January 25, 2004.....	61
3.3	Diversion Schedules for Test Scenarios showing months at specified discharge..	91
4.1	Maurepas Water Level Statistics: November 2002 to November 2003	102
4.2	Stressor Conditions at Shaffer et al. (2003) Maurepas Swamp Stations With and Without Diversion.....	119
4.3	River influence after 2 months at Shaffer et al.(2003) stations from tracer(10ppt) introduced with river water for 500, 1500 and 2500 cfs discharges.....	129
4.4	Predicted nitrate removal for 500, 1500 and 2500 cfs discharges.....	132
4.5	Predictions for Maurepas Forest Nutrient Loading ($\text{g m}^{-2} \text{d}^{-1}$).....	135
4.6	SWAMPSUSTAIN Predictions for Maurepas Forest Sustainability.....	140
4.7	Effect on Years to Sustainability in Tier 1 Cells of Changing SWAMPSUSTAIN Parameters.....	143

LIST OF FIGURES

1.1	Pontchartrain Basin showing location of the Maurepas study area.....	2
1.2	Proposed alignment for a diversion at Hope Canal.....	3
2.1	Maurepas Study Area.....	16
2.2	Photograph of Blind River at Station 10	18
2.3	Amite River Discharge: summary from USGS water resources data 2000	19
2.4	Photograph of Hope Canal near Station 8	20
2.5	Photograph of Reserve Relief Canal at Station USGS2.....	22
2.6(a)	Mean Salinity at Pass Manchac: 1951 – 2000 (from US Army Corps of Engineers, New Orleans district).....	24
2.6(b)	Mean annual and monthly Salinity at Pass Manchac: 1955 – 1981, and during the 1998 to 2000 drought (from US Army Corps of Engineers, New Orleans district).....	25
2.7	Photograph of Dutch Bayou at Station 9 looking downstream with ADCP on right and WL gage on left.....	26
2.8	Photograph of North Swamp near URS N gage.....	27
2.9	Forest monitoring sites from Shaffer et al. (2003).....	29
2.10	Lake, Amite, Hope and Reserve water quality sampling sites occupied by Lane et al. (2003) in 2000.....	32
2.11	Distribution of UNET swamp cells for modeling nutrient processing by Lane et al. (2003).....	36
2.12	Relationship between nitrate loading and removal efficiency from Mitsch et al. 2001.....	37
3.1	Water quality sampling stations occupied monthly from April, 2002 to May, 2003.....	40

3.2	Maurepas hydrologic gages and Shaffer et al. (2003) forest monitoring stations.....	43
3.3	Maurepas swamp elevations (ft, NAVD88) derived from LIDAR and applied to TABS model	57
3.4	Maurepas hydrodynamic model domain showing FE grid, flow boundaries and the stage boundary at Pass Manchac.....	58
3.5(a)	Calibration series: predicted and observed water level at S4 for December 26, 2003 to January 25, 2004.....	62
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S4 for December 26, 2003 to January 25, 2004.....	63
3.5(b)	Calibration series: predicted and observed water level at S9 for December 26, 2003 to January 25, 2004.....	64
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S9 for December 26, 2003 to January 25, 2004.....	65
3.5(c)	Calibration series: predicted and observed water level at S10 for December 26, 2003 to January 25, 2004.....	66
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S10 for December 26, 2003 to January 25, 2004.....	67
3.5(d)	Calibration series: predicted and observed water level at SLU A for December 26, 2003 to January 25, 2004.....	68
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at SLU A for December 26, 2003 to January 25, 2004.....	69

3.5(e)	Calibration series: predicted and observed water level at S11 for December 26, 2003 to January 25, 2004.....	70
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S11 for December 26, 2003 to January 25, 2004.....	71
3.5(f)	Calibration series: predicted and observed water level at S5 for December 26, 2003 to January 25, 2004.....	72
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S5 for December 26, 2003 to January 25, 2004.....	73
3.5(g)	Calibration series: predicted and observed water level at URS N for December 26, 2003 to January 25, 2004.....	74
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at URS N for December 26, 2003 to January 25, 2004.....	75
3.5(h)	Calibration series: predicted and observed water level at S16 for December 26, 2003 to January 25, 2004.....	76
	Calibration series: Scatter around 1:1 matchline between predicted and observed water level at S16 for December 26, 2003 to January 25, 2004.....	77
3.6	Validation: predicted and observed (ADCP) velocity at S9 for January 9, 2004 to January 23, 2004.....	80
	Validation: Scatter around 1:1 matchline between predicted and observed (ADCP) velocity at S9 for January 9, 2004 to January 23, 2004.....	81
3.7	Validation: Model predictions of salinity for two months at swamp stations from Shaffer et al (2003) beginning with a uniform 7 ppt distribution and 10 ppt at the Pass Manchac boundary.....	82

3.8	Validation: Model prediction for salinity after 302 hours, compared with values observed by Lane et al. (2003) for September 2000	84
3.9	LIDAR return count from different elevation slices at representative stations in the Maurepas swamp forest.....	86
3.10	Mapping the Maurepas Canopy Index (CI) from LIDAR in the winter.....	88
4.1	Water quality data for each region in the Maurepas swamp from April 2002 to May 2003.....	98
4.2	Si:N:P ratios for four Maurepas region from April 2002 to May 2003.....	100
4.3(a)	Lake Group water level time-series in first year: November 2002 to November 2003.....	104
4.3(b)	Lake Group water level time-series in second year: December 2003 to January 2004.....	105
4.4	River Group water level time-series in second year: December 2003 to January 2004.....	107
4.5(a)	Diversion Group water level time-series in first year: November 2002 to November 2003.....	108
4.5(b)	Diversion Group water level time-series in second year: December 2003 to January 2004.....	109
4.6(a)	Swamp Group water level time-series in first year: November 2002 to November 2003.....	111
4.6(b)	Swamp Group water level time-series in second year: December 2003 to January 2004.....	112

4.7	Canal Group water level time-series in second year: December 2003 to January 2004.....	113
4.8	Synoptic Water Level in Channel and Swamp at S9: January 2003 to November 2003.....	116
4.9(a)	Predicted Influence of Amite River Discharge.....	117
4.9(b)	Predicted Influence of Amite River Discharge.....	118
4.10	Predicted water level response at Shaffer et al. (2003) swamp sites to 500, 1500 and 2500 cfs diversion discharges.....	121
4.11	Predicted influence of diversions on water level after 0.5 months.....	122
4.12	Predicted influence of diversions on salinity after 2months.....	126
4.13	Predicted influence of diversions on conservative tracer transport. after 1 month.....	127
4.14	Predicted flow direction and velocity at in the swamp.....	128
4.15	Sensitivity of Tier 1 and Tier 2 Swamp Cells to Discharge.....	142
4.16	Sensitivity of Tier 1 and Tier 2 Swamp Cells to Sediment Concentration	145
4.17	Sensitivity of Swamp Cells to Consolidation Coefficient	146
4.18	Forecast Swamp Restoration Trajectories for Discharge Scenarios A (diamonds), B (squares), C (triangles) and D (X's).....	147

EXECUTIVE SUMMARY

Design is proceeding on a project to divert up to 2,500 cubic feet per second (cfs) of Mississippi river water into the Maurepas swamp, an almost permanently flooded estuarine cypress-tupelo (*Taxodium distichum* – *Nyssa aquatica*) forest south of Lake Maurepas in Louisiana. Baseline hydrologic and water quality information acquired during normal rainfall years was compared with similar data acquired during the drought of 2000. N:P ratios of 16:1 and greater, higher than the Redfield ratio threshold, were found only in samples from the Amite and Blind Rivers that receive runoff from developed areas. Si:N ratios never fell below 1:1. Low N:P and high Si:N ratios indicate that the Maurepas basin is almost always nitrogen limited and will respond to additional river-derived nitrogen through increased plant production, particularly for algae and floating vegetation, even if other nutrients are not increased.

Hydrodynamic and water quality models simulated up to three months continuously, but were then linked to longer horizon ecological algorithms to answer questions about nutrient uptake and the likely response of the forest community to diversions operated at maximum discharges of 500, 1,500 and 2,500 cfs (14, 42 and 71 m³ s⁻¹). Light Imaging Detection And Ranging (LIDAR) data acquired in 1999 was used to construct the topography of the receiving swamp that ranges in elevation between 1.0 and 1.8 ft (NAVD88), and averages 1.15 ft. The mean tide elevation, in contrast, is 1.5 ft, meaning that the swamp is sinking relative to mean sea level so that much of the forest is now permanently inundated.

TABS finite-element hydrodynamic and water quality models predicted that water levels would be raised by less than 0.25 ft under discharge scenarios ranging from 500 to 2,500 cfs and that flows were fully developed in less than one month.

A 2,500 cfs diversion reduced Lake Maurepas salinity by 30 percent after only one month, showing one important benefit to a swamp forest that experienced salinities greater than 5 ppt in fall 2000.

The simulated diversion, studied using a tracer approach, expanded radially and showed little distortion by topography or channels. River water was introduced with an initial nitrate concentration of 1.5 ppm. The model predicted that 99 percent of all nitrate introduced in the 500 cfs diversion would be retained or removed before it reached the nearest open water boundary. Reduction decreased to 90 percent for a 1,500 cfs diversion, and to 86 percent for a 2,500 cfs discharge. Nitrate loadings in the swamp cells adjacent to Hope Canal range from 0.1 to 0.5 g m⁻² d⁻¹ (37 to 183 g m⁻² y⁻¹), comparable to rates measured in the Atchafalaya River estuarine complex (Lane et al. 2002) and in experimental wetlands along the Olentangy River, Ohio (Spieles and Mitsch 2000, Mitsch et al. 2001).

Mean nitrate concentration for river water reaching Blind River or the Lake is predicted to range from 0.05 to 0.15 to 0.19 mg-N L⁻¹, respectively, for 500, 1,500 and 2,500 cfs diversions. The value for a 1,500 cfs diversion is higher than concentrations measured in 78 percent of samples acquired during the baseline period, but is within one standard deviation of the mean observed in 2002-2003.

The mean exit concentration predicted for a 2,500 cfs diversion is greater than values measured in 96 percent of all samples collected, and is slightly more than one standard deviation above the mean. This analysis supports the earlier finding that a 1,500 cfs

diversion will provide a significant nutrient infusion to more than 10,000 ha of nutrient deprived swamp forest, about half of the swamp south of the Lake, while reducing transiting nitrate by 90 percent to background levels.

The hydrodynamic and water quality models are too computationally intensive to continuously simulate more than a few months in the prototype. Such models cannot directly drive an ecological model for a period of 50 to 200 years, the appropriate time frame over which forest evolution should be evaluated. A hybrid modeling approach, SWAMPSUSTAIN, was developed to bridge the gap between the hydrodynamic model and a fully functional Individual Oriented Model (IOM). SWAMPSUSTAIN calculates the years necessary at a given discharge schedule (scenario) for the swamp in each cell to reach 0.4 ft above mean sea level, the target elevation for sustainability. SWAMPSUSTAIN predicts that between 2,000 and 4,000 ha of the Maurepas swamp can be restored to sustainability within 50 years if average yearly diversion discharges greater than 1,000 cfs are initiated. This leaves a substantial portion of the project area that will benefit from salinity control and nutrient addition, but in which the forest will not be restored to sustainability without additional restoration efforts. Restoration program planners can use this information to build the case for (1) adding additional Mississippi River diversions up or downstream, and (2) augmenting the diversion with other restoration efforts in the project area.

Dredging sediments from Lake Maurepas and pumping them into the swamp, for example, could quickly create additional islands of sustainable wetlands outside the area of swamp that can be restored by the proposed diversion alone.